MAZE

Investigation and Design
Of a Power Plant
For Mahomet, Illinois

Electrical Engineering

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INVESTIGATION AND DESIGN

OF A

POWER PLANT FOR MAHOMET, ILLINOIS

BY

EVERET ANDY MAZE

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

ELECTRICAL ENGINEERING

COLLEGE OF ENGINEERING
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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

EVERETT ANDY MAZE

ENTITLED INVESTIGATION AND DESIGN OF A POWER PLANT

FOR MAHOMET, ILLINOIS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Electrical Engineering

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INVESTIGATION AND DESIGN OF A POWER PLANT FOR MAHOMET, ILLINOIS.

Introduction.

Mahomet, Illinois is a little village of eight hundred inhabitants, located ten miles west of Champaign on the Big Four Railroad. The occupations of the inhabitants consist mainly of the pursuits which are common to nearly all small places located in the farming communities in central Illinois. The various enterprises consist of blacksmithing, lumber yards, tile yard, stores, bank, etc. The fact that a bank is located there indicates that the people are somewhat prosperous; the brick and concrete side walks; the way the streets are kept and other municipal improvements, shows in general, that the people take an interest in their local affairs. There are also several well built dwellings occupied by retired farmers. The village school is one of modern type.

There is no probability that the village will decrease in size, or that the land in the community will become less valuable. In fact this village was founded in the Eighteen Forties and has been steadily growing. The growth in the past has been slow, but steady without boom or any great disasters, and it is safe to assume that its rate of growth in the future will be much the same as in the past.

In one respect Mahomet is behind many other villages of its size; in that it has no means for lighting the streets or the business portion of the town. The streets at present are not lighted and on dark winter nights during the wet season, the streets are difficult to travel over.

After a little investigation it was found that the people of Mahomet desired their streets lighted, also many of their stores and dwellings. Since this is an age of the small power plant, the author being interested in power plant installation and operation, decided to design a cheap and effective power plant for the place; as the village board was willing to consider an attempt in that direction. The object of the present design is to determine whether a power plant for this village will pay all of its operating expenses and will prove beneficial to the community as a whole.

A map of the municipality was obtained, and the buildings to be supplied with lights located thereon; the street lights were also located after a careful personal survey of the place. On account of the scattered nature of the village, and the fact that no motor load will be required, it was decided that the best system of distribution was high tension alternating current; each transformer being placed near the center of distribution and furnishing lights for the various near by buildings.

Since there will be no day load, all of the revenue will be obtained from the house and street lighting. As the incandescent lamps in the buildings will not all be on and will not burn long except upon infrequent occasions, and since the street lighting load is small, the total revenue obtained will be small. For this reason the plant must have as low a first cost as possible, consistent with good service. Low salaried men must be employed for the operation of such a plant so as to decrease expenses, and for this reason also simple machinery

must be selected. It was found that the maximum full load capacity on the plant will be 30 K.W. which also provides for future growth. As shown on the map the location of the power house is not near the center of distribution, but is located for convenience in obtaining water and coal supply, also to be able to utilize part of its capacity as a pumping plant when running less than full lighting load. Wires comprising the primaries and street lighting circuits will be placed on the same pole line whenever possible. Poles will be of sufficient height to clear telephone wires and other obstacles.

On the following pages are given lists of machinery, transformers and materials; the location of all apparatus; prices and the reasons for the selection of the apparatus chosen.

Street Lighting.

As the Village of Mahomet covers a large territory in comparison with the population it is found advisable to use series incandescent street lighting, as this system affords a better distribution of light over the village, than the arc light system at a minimum cost. If the village had been closely settled there might have been occasion to consider the system of arc lighting. The requirement of street lighting is not to give a maximum light at one place and leave portions dark; but to give an even distribution of light.

The ordinary arc lamp consumes approximately 650 watts, which is equivalent to 11 sixteen candle power incandescent lamps. Now if 50 candle power incandescent lamps were used there can be 7 places, giving out 50 candle power each instead

of two places giving out 176 candle power each.

In the choosing the method of lighting the streets of a village, such as Mahomet, several other important questions must be considered: first, price received from village for street lights; second, importance and necessity of lighting certain portions; third, arc lights are much more expensive to install, maintain and operate than series incandescents. Again much of the light is of no practical use throughout a great part of the year by the shading of trees which line practically all streets. But the business section of the village, will naturally require more brilliant light than other sections; this section being about two blocks long.
If necessary, arc lamps may be furnished, supplied with current from near by transformers. With the above requirements given due consideration it appears, to follow the best practice, that the streets of the Village of Mahomet should be lighted by series incandescent lamps, located on streets as shown on map. A complete installation of these lamps, up to the terminals of the alternator is given in table No. 1. In this table will be included the three 110 volt arc lamps used to show up the business portion of the town and the railroad station. The two arcs for lighting the business district are located at the intersection of Lincoln and Main Streets, and Elm and Main Streets. The third arc is on the north side of the railroad on Sangamon and Walnut Streets.

Description of Series Incandescent Circuits.

Two separate 1100 volt alternating circuits lead from the power house, which is located in the south-east part of town.

One circuit feeds the series lights south of Main and west of Elm Streets. The other circuit feeds all series lights on Elm and east of Elm Street and on Main and north of Main Street. Each circuit contains 24 incandescents. The incandescents used will be 50 candle power; which will take 3.5 watts per candle power, or 45 volts and 3.6 amperes. Since incandescents are to be used for street lighting, a constant current will flow, and no constant current transformer will be required. Voltage will be regulated at the power house by means of lamp banks. When one lamp on the circuit goes out there will be a corresponding rise in the current passing through the ammeter placed in that circuit.

Both circuits have been so laid out, and the size of wire calculated so as to use the entire 1100 volts. The drop in the west circuit is 34 volts and 1080 volts are used up in the lamps, giving 1114 volts required in the circuit. This is 14 volts too large, or it causes each light to have .3 of a volt less than required. The north circuit has a drop of 36 volts and 1080 volts are used up in the lamps, giving 1116 volts required in the circuit, or it causes each light to have .35 of a volt less than required. Both circuits will be run with number 8 wire.

The Westinghouse Street lighting shunt coil, is a device intended to be used in shunt with the incandescent lamp, in a series circuit connected to a constant potential source. Its object being to prevent an open circuit when a lamp burns out, or is disconnected, and to prevent the voltage of the remaining lamps from rising above normal, when any one or more

lamps are out of the circuit. It is automatic in its action. This system of regulation was found expensive and abandoned, and the Thomson Houston base and cut out used instead. Regulating being done by lamp-banks as before mentioned. All lamps are to be suspended by an 8 foot over hanging mast arm, which will be placed 15 feet above the ground, this giving sufficient room beneath.

Pole Line.

A map of the village was obtained, and the buildings which were to be supplied with electricity were located; the street intersections which were to be lighted were also located; after a careful personal survey of the place. The location of street lights and the buildings that were to be provided with lights determined the location of the pole line. The pole line was so placed that primaries and series circuits could be run on the same poles with the least waste of copper. Two things enter into the determination of the location of poles. First, balancing the expense of a shorter route to save copper against an out of the way route to save poles. Second, if it is cheaper to string more wire and save a pole or two; will the drop in the line allow you to use the cheaper way. All of these conditions have been taken into consideration in the laying out of the various circuits. From calculations it is found that a No. 8 wire is large enough to carry the required current within the allowed drop. The smallest wire used is No.8 as that of less diameter is not strong enough for over head wiring because of the heavy sleet which sometimes envelopes it.

Poles will be placed 100 feet apart for several reasons. First, the blocks are of such a nature that poles placed more, or less than 100 feet apart do not fit the blocks. Second, wires must clear trees and cannot have much sag. Third, wires out of the way of trees saves constant repairs. The larger the sag is in a line the further apart poles can be placed. Now allowing 21000# as the tensile strength of copper per square inch, and with a 2 foot sag between poles using No.8 wire it is found that the maximum distance that poles can be placed is 294'. This does not allow for any factor of safety for sleet or winds. Poles placed every 100 feet apart allow a factor of safety of 3 which will take care of all sleet and wind loads with a minimum expenditure for repairs.

Service for Buildings.

The method of lighting the houses of Mahomet is to send alternating current to small transformers, which are situated near the center of distribution. The voltage of the primaries is 1100 volts; ratio of transformation at the transformers being 1 to 5. Since there is some drop in the wires on both high and low tension side, the voltage on some lamps will be slightly less than on others, such lamps being located further away from plant. In no case, however, is the drop more ~~or less~~ than 3.9 percent at the transformer. To determine the size of transformers, all houses were located and the required number of lights for each determined. The number of lights to be fed by each transformer is determined, one-half being assumed to be the maximum number of lights on at any one time.

The transformers are numbered and table No. 1 and map No.2 gives the largest drop to transformers from no load to full load, their location and cost. Since there is drop in both primary and secondary wires, 110 volt lamp will not be placed in dwellings, but lamps of 108 or 106 volts instead, according to the drop in the line. In determining the size of the primary wires to be used in the various parts of the primary circuit, it was assumed that the greatest drop therein should not exceed four percent, when all the transformers on the line were loaded to their rated capacity. In this way the wire required from the power house to the various transformers was determined. Thus, if it were found that one transformer 800 feet away required No. 10 B and S wire, and another transformer 1000 feet away required a No. 8 B and S wire, a No. 6 wire would be used from the station to the first transformer.

Table No. 1

No. corresponding to location of Trans.	Size of Transformers in K.W.	Drop in % from station to Trans.	Cost.
1	1	2.3	$19.00
2	.5	2.6	17.00
3	1.5	2.5	25.00
4	2.5	3.1	30.00
5	1.5	3.2	25.00
6	1	3.9	19.00
7	2	3.2	28.50
8	2	1.9	28.50
9	5	2.6	45.00
10	1	3.78	19.00
11	1.5	3.78	25.00
12	1	2.9	19.00
13	1	3.54	19.00
Total	20.25		$319.00

Transformers in the above table ~~is~~ are for 1100 volt primary circuit; 60 cycles ratio 5 to 1.

Cost of Line Construction.

In table No. 2 are estimated costs of line construction, including series incandescent circuits, arc lamps, pole line and primaries up to the transformers, ready for the secondary distribution.

Table No. 2

No.			
167	30 ft; 5 in. at top; cedar poles delivered @	\$3.00--	\$501.00
2	40 ft; 5 in. at top; cedar poles delivered @	4.00--	8.00
161	poles, shaved, housed, gained and buts painted	.50	80.50
161	poles, digging hole and setting @	.50	80.50
50	Series Columbia Incandescent lamps 50 C.P. @ \$30.00 per 100		15.00
50	Thomson House cut outs @	.08	4.00
3	Arc lamps A.C. 60 cycle; 110 volts; @	23.00	69.00
3	6 ft. arc lamp mast arms @	3.90	11.70
47	8 ft. incandescent mast arms complete @	4.30	202.10
200	ft. of lamp chain @ .30 per 100 ft.		.60
50	Strain insulators at \$35.00 per 1000		1.75
15	5 in. strombaugh guy anchors @	.45	6.75
200	ft. 3/8" galvanized stranded messenger wire @ \$10.00 per 1000 ft.		2.00
115	4 pin 4'x $3\frac{1}{4}$" x $4\frac{1}{2}$" cross-arms @	.20	23.00
110	2 pin 3'x $3\frac{1}{4}$" x $4\frac{1}{2}$" " " @	.15	16.50
600	Western Union Cross arm pins @ \$7.15 per 100		42.90
450	20"x 1"x 3/16" galvanized cross arm braces @ \$36.00 per 1000		16.20
225	lag screws 5/16" dia. $1\frac{1}{2}$" long @ \$1.05 per 100		2.35
225	9"x 3/18" through bolts @ \$5.45 per 100		12.30
450	4"x $\frac{1}{4}$" carriage bolts @ \$1.50 per 100		7.75
1000	3/8" washers (10# per 100) @ .06 per lb.		6.00
500	4/8" " (15# per 100) @ .06 " "		4.50
300	3/8" round iron steps at \$2.75 per 100		8.25

No.			
700	Deep grooved insulators	@ .04	$28.00
8	1100 volts, pole lightning arresters	@ $4.00	32.00
12	Tree insulators	@ 3.80 per doz	3.80
26	Transformer fuse plugs	@ .80	20.80
1	Cut out switch	@ 1.00	1.00
20¼	K.W. in small sizes of transformers		319.00
	Length of #8 wire in north circuit of incandescents allowing 5% waste is 14973 ft; cost @ .15 per 1# . .		168.40
	Length of #8 wire in west circuit of incandescents allowing 5% waste is 15860 ft; cost @ .15 per 1# . .		178.40
	Length of the various sizes of wire used in the primary circuit allowing 5% for waste no. 6-2100 ft. (1000 ft. weighs 121#) @ .15		48.20
	No. 7-9765 ft. (1000 ft. weighs 98#) @ .15		143.55
	No. 8-10426 ft. (1000 ft. weighs 75#) @ .15		117.30
	Estimated cost to string wire @ $11.00 per mile 9.45 mi.		103.95
13	transformers to hang at $1.00 each		13.00
	Total cost of Incandescent circuits and primary circuit complete.		$2301.05

Table No. 3

Cost of Secondary Distribution.

No.			
45	25 ft; 5 in. at top, cedar poles delivered	@ $2.00..	$90.00
45	poles; shave, housed, gained & buts painted	@ .50	22.50
45	poles; digging holes and setting	@ .50	22.50
100	ft, 3/8" galvanized stranded messenger wire @ $10.00 per 1000'		1.00

No.				
120	2 pin 3"x $3\frac{1}{4}$"x $4\frac{1}{2}$" cross arms	$ .15	. . ,	$18.00
240	Western Union cross arm pins	@ $7.15	per 100.	17.15
120	Lag screws 5/16" dia. $1\frac{1}{2}$" long, galv.	@ 1.05	. . . .	1.25
240	4"x $\frac{1}{4}$" carriage bolts	@ 1.50	per 100.	3.60
400	3/8" washers (10# per 100)	@ .06	per #	2.40
200	$\frac{1}{2}$" " (15# per 100)	@ .06	per #	1.80
300	Wooden pole brackets	@ 1.20	per 100.	3.60
600	Deep groved insulators	@ .04	. . .	24.00
Length of the various sizes of wire used in the secondary circuits allowing 5% for waste				
No. 8-19,140 ft.		@ .15	per lb.	281.00
No. 7-16,000 ft.		@ .15	" "	180.00
Cost to string wire		@ 10.00	per mi.	66.50
115	Westinghouse Integrating Wattmeters 5 ampers; 110 volt; 60 cycle; 3 wire	@ 13.50	each	1365.00
	Secondary circuits complete. Total			$2080.80

Machinery.

In choosing the generator, engine, and boiler for the power house, the full load on the bus-bars is taken as the sum of the full load on each of the transformers plus the additional load for street lighting and line losses. The aim in the selection of the machines, was to obtain standard sizes and machines which would allow for an increase in the out put of the plant. Machines to be able to stand an overload of twenty per-cent at least two hours without injury, and have the highest efficiency, for machines of their type and out put. The generator is three phase which will be now single phase; giving

approximately three fourths of its rated out put at single phase. With this selection one coil can be burnt out without undue delay in the plants operation. This really provides a secondary machine for the plant, in case of a burnt out coil in the armature and machines of this type for small plants should be installed. It is true that the first cost is slightly greater, due to one third more copper being placed on the armature. In all other respects a single phase machine is the same as a three phase machine. Manufacturers often wind armatures of a three phase machine for single phase and furnish the same machine to the buyer as a single phase machine; the only difference between the single phase and the three phase is that one third of the copper has been left out of the armature. The normal full load on all the transformers is $20\frac{1}{4}$ K.W. The full load on street lamps is 8.4 K.W. and adding to this the 1.35 K.W. allowed for loss in transmission, makes the normal full load on the generator 30 K.W.
The power delivered at the pulley is 33 K.W. to drive the large generator; but in addition to this there must be $1\frac{1}{4}$ K.W. more power supplied as the exciter is direct belted to generator.

The engine best adapted for this plant is the simple high speed; its selection being determined by various factors. First, cost of coal; second, efficient engines such as the Corliss are not made in small sizes; third, load factor.
The cost of coal plays an important part in the selection of engines. If coal is cheap, a cheap engine can be installed, and be uneconomical in its steam consumption per H.P. Hr. Engines of high efficiency are very expensive in the smaller

sizes that are on the market. The load-factor should not be over looked. If the load factor is small, cheap engines should be used. If the load-factor is small the engines and machines are idle a greater part of the time and the interest and depreciation on such machines should be as little as possible. With the installation of a simple engine the first cost is reduced and the interest, and depreciation and various other expenses are reduced. The engine selected should be large enough to carry an over load at times without injury. The mechanical efficiency of this engine will be about 80%. The required H.P. of engine with 80% mechanical efficiency to drive 34¼ K.W. generator is 60 H.P. The engine selected will carry an over load without undue change of speed from its normal full load speed. The steam consumption required per H.P. Hr. is 30# at 90# pressure.

The boiler best suited for this station is the fire tube type, for it is much cheaper, and almost as durable as a water tube boiler. Calculating the size of boiler needed to supply the required amount of steam at 90# pressure; from and at 212° with feed water heated to 100° F. gives the required size of boiler as 55 H.P. Since the boiler will be required to supply auxiliaries, a larger size will be needed in order to provide for such auxiliaries and to take care of over loads. For this reason a 60 H.P. boiler will be used. In case the plant is running at a small load, the boiler will supply the large duplex pump.

The pump required will raise water 52' plus the additional head lost in friction in 1100' of 4" delivery pipe, which

amounts to 20 ft. head lost in friction. The pump will deliver 150 gallons of water per minute against 72 ft. head.
The required theoretical H.P. of the pump is 2.72. This pump ordinarily consumes four times as much steam per H.P. Hr. as required by the engine; which will be 10.88 B.H.P. required to run the pump at its full load capacity.

The above selected types were chosen in accordance with the specifications for the Mahomet Power Plant. The aim being to select machines with economical operation and with the highest efficiency for this particular type of plant.

Engine.

60 H.P. Simple; Non-condensing; Automatic; Self-contained; 300 R.P.M., 12" stroke; $9\frac{1}{2}$" diameter; fly wheel 54" diameter; $10\frac{1}{2}$" width; floor space 9' 4"x 4' 7". Water rate 30# per I.H.P. Hr. at 90# steam pressure. Weight 3 tons.
Engine built by The Phoenix Iron Works, Meadville, Pa.

Cost of engine	$874.00
Engine setting	98.00
Labor to place engine on foundation	15.00
Freight	18.00
Total cost of engine set.	$1005.00

Boiler

60 H.P. Stationary; horizontal return; fire tube boiler Diameter 54"; heating surface 650 sq. ft.; grate surface $20\frac{1}{4}$ sq.ft.; floor space 19' 10"x 9'. Boiler built by The Erie Iron Works, Erie, Pa. Weight 6 tons.

Cost of boiler	$434.00
Boiler setting	274.00
Cost of placing boiler on setting . .	25.00
Freight on (20,000 brick) from Danville	15.00
Freight on boiler	50.00
Total cost of boiler set.	$798.00

Generator.

National Electric; 40 K.W.; 3 phase; 60 cycles; 1100 volts; revolving field; belt driven; 1200 R.P.M. generator. Length over all 4' 6"; width over all 3' 6". Field excitation 110 volts; 6 ampers. Weight 3 tons. Generator is provided with slide rails and adjusting bolts.

Cost of generator	$800.00
" " foundation	42.00
" " placing generator on foundation	12.00
Freight	7.00
Total cost of generator set.	$861.00

Exciter.

National Electric $1\frac{1}{4}$ K.W.; D.C.; 110 volts; compound wound; 1800 R.P.M.; belt connected exciter. Length over all 2'; width over all 1' 6" Weight 200#

Cost of exciter	$60.00
Cost of setting	1.00
Freight	8.00
Total cost of exciter set.	$69.00

Boiler Feed Pump.

Buffalo Duplex Boiler Feed Pump. Working pressure 150# Capacity 11 gallons per minute; diameter of steam cylinder 3"; diameter of water cylinder 2"; length of stroke $3\frac{1}{2}$". Floor space 12"x 30". Pump brass fitted; bronze piston rods; water pistons; sleeves; valve seats; bolts; springs and stuffing box glands. Weight 150 #

Cost of pump	$50.00
Cost of setting	1.00
Freight	8.00
Total cost of pump set.	$59.00

Large Pump.

Dean Brothers Durable Duplex Outside Plunger Packed Pump. Working pressure 150#. Capacity 95 gallons to 165 gallons per minute. Diameter of steam cylinder 10"; diameter of water cylinder 7'; length of stroke 10". Floor space 93"x 21". Weight 950#. Pump including bronze plungers, stuffing box glands; valve seat; bolts and plates.

Cost of pump	$225.00
Cost of setting pump	8.00
Freight	20.00
Total cost of pump set.	$253.00

Feed Water Heater.

Sims' Vertical Closed Feed Water Heater. Capacity for a 60 H.P. Boiler. Height 3' 9"; diameter 1' 10". Weight 550#.

Cost of heater	$105.00
Cost of setting	5.00
Freight	15.00
Total cost of heater set.	$125.00

Injector.

The Metropolitan Automatic Injector for feeding 60 H.P. Boiler. Capable of raising hot water 10'. Injecting feed water at 100 F. against 100# steam pressure.

Cost of injector	$40.00
Freight	.50
Total	40.50

Steam Separator.

Horizontal Steam Separator for 5" pipe.

Cost $48.50.   Freight $2.50   Total cost $51.00.

Steam Trap.

One, Anderson Steam Trap for $\frac{3}{4}$" pipe. Maximum discharge 5# of water per minute.

Cost $14.50   Freight $1.00   Total cost $15.50

Safety Valve.

2$\frac{1}{2}$" Nickle Plated, Crosby Pop Safety valve $13.50.

Lubricators.

Detroit Improved Sight Feed Lubricators.

Two, $\frac{1}{2}$ pint polished brass lubricators @ $4.25 ..	$8.50
One 1/3 " " " "	5.50
Total cost of lubricators.	$14.00

Gage.

Double Spring Bourdon pressure gage, with siphon 6 inch in diameter. Graduated 0 to 125# pressure. Cost. $ 5.40

Water Column.

Cast iron body. "Retrance Safety Water Column", with combined high and low water alarm, provided with steam and water cocks. Steam connections $1\frac{1}{4}$"; blow off $\frac{3}{4}$". Cost complete $12.00

Damper.

"Clark Damper Regulator", operated with chains from the front of boiler. Cost complete . . . . $ 7.00

Foot Valve.

Five inch, Iron body, Eddy Bronze. Mounted vertical Foot Valve. Rubber faced gates with brass wire screens. Cost . . . . $ 2.10

Float Valve.

$1\frac{1}{4}$", Vertical Automatic Float Valve. Cost . . . . $ 7.00

Steel Tank.

Vertical Open Steel Tank. Capacity 20 bbl. Cost	$16.00
Cost of placing tank on top of building	2.50
Total Cost	$18.50

Steel Passage to Stack.

30' Steel structure for passage of flue gases to stack, cost including erection $30.00

Piping.

The size of live steam piping is determined by the number of pounds of steam required by the engine, which for the above engine is 30# per H.P. Hr. at 90# steam pressure. It is found that a 3½" pipe is the proper size when the engine is running at full load; but as steam is to be supplied to the pump a 4" pipe was used. The various sizes of steam pipe were determined by consulting tables. The size depending on the number of valves, tees, separators and the allowable drop in pressure in the pipe. The main exhaust pipe has a diameter of 5" and goes directly from the engine to the feed water heater. The exhaust piping is so arranged that the heater can be cut out of the exhaust line. Water is raised from the Sangamon River, by the large pump, into a reservoir placed on top of the building; which is automatically kept full by a float valve, from which water flows by gravity to the feed water heater. This tank is of sufficient size to supply the boiler when running at full load 3½ hours and serves as a setteling tank and as a means of supplying water to the heater when the pump is not running. There is also a secondary means of supplying water to the heater directly from the railroad tank. Piping is so arranged that water can be taken around the heater, and either hot or cold water can be supplied to the boiler pump or injector.

Lengths of the various sizes of piping required for live steam mains, exhaust, and water mains.

Heavy wrought iron.

Size of Pipe.	Length.	Cost.
5"	155'	$ 25.60
4"	1283'	134.70
$2\frac{1}{2}$"	8'	1.00
2"	30'	2.50
$1\frac{1}{2}$"	15'	1.00
$1\frac{1}{4}$"	48'	2.50
1"	25'	1.25
$\frac{3}{4}$"	10'	.50
Total cost of piping		$169.05

Valves.

Iron body globe valves, yoke top.

Size of valve.	Number.	Price each.	Cost.
5"	6	$5.40	$32.40
4"	4	3.20	12.80
Without yoke top.			
$2\frac{1}{2}$"	2	1.00	1.00
2"	1	.30	.30
$1\frac{1}{2}$"	2	.30	1.60
$1\frac{1}{4}$"	6	.70	4.20
1"	2	.50	1.00
$\frac{3}{4}$"	1	.40	.40
$\frac{1}{2}$"	1	.30	.30
Total cost of Valves			54.50

Elbows, Wrought Iron.

Size.	Number.	Price each.	Cost.
5"	7	$1.50	$10.50
4"	4	.90	3.60
2"	2	.20	.40
$1\frac{1}{2}$"	1	.35	.35
$1\frac{1}{4}$"	6	.35	2.10
$\frac{1}{2}$"	2	.30	.60
$\frac{3}{4}$"	2	.30	.60
1"	2	.30	.60
	Total cost of elbows		$18.70

Tee connections.

5"	1	$1.50	$1.50
2"	3	.30	.90
$1\frac{1}{4}$"	1	.20	.20
1"	1	.15	.15
$1\frac{1}{4}$"	1 four way	.30	.30
	Total cost of Tees		$3.05

Heavy wrought iron couplings.

5"	13	.50	$6.50
4"	55	.30	16.50
$1\frac{1}{4}$"	5	.10	.50
	Total cost of couplings		$23.50

Heavy wrought iron unions.

Size	Number.	Price each.	Cost.
4"	1	$1.30	$1.30
$2\frac{1}{2}$"	3	.60	1.80
$1\frac{1}{4}$"	3	.25	.75
1"	1	.20	.20
	Total cost of unions		$4.05

Pipe Hangers.

4"	3	1.75	5.25
$2\frac{1}{2}$"	2	.75	1.50
	Total cost of Hangers		$6.75

Summary of Cost of Piping.

Cost of pipe	$169.05
" " valves	54.50
" " elbows	18.70
" " tees	3.05
" " couplings	23.50
" " unions	4.05
" " hangers	6.75
" " painting and pipe covering	10.00
Freight	30.00
Cost of labor to erect piping and make all the various connections	80.00
Total cost of piping in place.	$399.60

Cost of Belting.

One, oak tanned leather, double thickness, cemented joints; 7" wide; 52' long @ $1.00 per square foot. Cost $36.40

One, oak tanned leather, single thickness; cemented joints; 3" wide; 18' long @ $ .75 per square foot Cost 3.40

Total cost of belting $39.80

Lightning Protections.

Six, double pole, non-arcing, station, A.C. arrestors, suitable for 1100 to 1250 volts. Each $12.60 Cost $ 75.60

Six, choke coils, suitable for 1100 volts, 7 to 50 ampers. Each $4.25 . . . . .Cost 25.25

Total cost of lightning protection 100.85

Switch Board Equipment.

Westinghouse; round type F voltmeter; 7200 alternations; provided with transformer, ratio 5 to 1; graduated 0-150; direct or alternating current. Cost $37.50

Westinghouse; round type F ammeter; 7200 alternations; graduated 0-40. Cost 33.00

Two, Westinghouse; round type F ammeters; 7200 alternations; graduated 0 to 5; with scale readings of one ampere. Each $33.00. Cost 66.00

Westinghouse, round type model K; D.C. ammeter; value of each scale division 2 amperes; graduated 0to 15 Cost 8.25

Four, Hill style D switches; provided with a marble barrier; suitable for 1100 volts and 100 amperes. (cannot be obtained in small current capacity) Each $5.45:21.80

Westinghouse; single throw; single pole type D switch;
D.C.; 25 amperes; 250 volts. Cost . . . . $ 1.10

One, Westinghouse; double pole; single throw; type D switch; D.C.; 25 amperes; 250 volts. Cost 2.10

Small rheostat for shunt field of exciter; resistance 65 ohms; 24 steps; 2.5 amperes first step; 1 ampere last step; minimum field resistance 50 ohms; suitable for 100 to 125 volts. Cost 7.50

Large rheostat for generator; resistance 12.5 ohms; 64 steps; 12.5 amperes first step; 5.5 amperes last step minimum field resistance 10 ohms; suitable for 125 volts. 17.00

Two; single pole; automatic; quick break circuit breakers provided with hand trip, suitable for 20 to 50 amperes and 1100 volts; alternating current. Each $16.50 Cost 33.00

For incandescent circuits; four circuit breakers similiar to the above description; suitable for 1100 volts A.C.; 3 to 6 amperes. Each (special) $18.00. Cost . . . 72.00

Two; single enclosed fuse boxes; suitable for 30 amperes and 250 volts. Each $ .30. Cost 60

Two; single enclosed fuse boxes; suitable for 80 amperes and 1100 volts. Each $ .40 Cost 80

Enclosed fuses for 1200 volts; 30 amperes. Each $ .30 Cost .60

Enclosed fuses for 250 volts; 20 amperes Each $ .15 Cost .30

Three pilot lamps and brackets. Each $ .75 Cost 2.25

Three panels 22"x 38" blue Vermont Marble. Each $6.00 . . 18.00

Cost of switch board iron frame complete 5.00

Cost of 300' of #6 wire for switch board and connections. 5.50

Cost of cleats and supports	$ 5.00
Cost of freight on all switchboard apparatus	10.00
Cost of errection and connections on switch board . . .	20.00
Total cost of switch board complete	$367.80

Building.

Location of power house and grade lines,(Surveyor)	$ 5.00
Excavation for building, 607 cu.yds. at .12½ per yard	75.90
112 cu.yards of concrete required for walls and foundations; @ $10.00 per cu.yd. including material labor and forms	1120.00
27 cu.yds. of concrete required for floors @ $8.00 per cu.yd. placed	216.00
46,000 hard, common brick @$7.00 per 1000 on the track at Mahomet	322.00
Three pairs of stair ways complete. Average $6.50 each	19.50
Two large doors. Average $10.00 each	20.00
Eight windows complete. Average $3.00 each	24.00
Railing around engine room	2.00
Six stringers, 8'x 1½'x ½' @ $ .50 each	3.00
Doors to cover coal bin	4.00
Cast iron plates for covering under floor pipes	6.00
1200 sq.ft. of common sheathing @ $2.00 per 100	24.00
Cost of sheathing roof @ $1.50 per day	9.00
1200 sq.ft. of tar and gravel roofing placed @ $10.00 per sq.ft.	120.00
Cost of store room	30.00
Cost of rafters 30-16'x 6"x 3" @ $150 each	45.00

Cost of rafters 14-16'x 6"x 3" @ $ .80 each	$ 11.20
Cost of erection of same	14.00
Two buffers complete @ $5.00 each	10.00
Cost for brick masons	115.00
Cost of wiring power house 12 lights @ $ .50 each . . .	6.00
Total cost of power house complete	$2201.60

Cost of Switch.

Surveyors	$ 10.00
150 ties @ $ .40 each	60.00
Rails $60.00; spikes $2.00; bed $10.00; labor $20.00	92.00
Total cost of track complete	$162.00

Cost of Excavation for Pipe Line.

Pipe line 1200' long, 3' deep 2' wide, 800 cu.yds.

@ $ .08 per cu.yd.	$ 64.00

Chimney.

In order to produce the desired rate of combustion necessary in the grate, cold air must be drawn through the fire at a greater difference of pressure than caused by the local difference in temperature. One pound of coal requires 10 to 12 pounds of air for its combustion. Anthracite requires less, and bituminous more according to its volatile matter.

For the best results in combustion an excess of air over that required chemically, is desirable varying from 18 to 24 pounds. The chimney should be located so as to give the least length of flue draft from the boiler to the chimney. The foundation should be porportioned and independent of the building.

The total weight of a brick chimney should be greater than the total wind pressure against it at any time. Every square foot of chimney exposed to the wind at one time should be designed to stand a wind pressure of 56 pounds per square foot. The circular chimney reduces the wind pressure to a minimum, makes the best flue and is economical in material. Allowance must be made where flues are longer than 50', and height added to the chimney to make up for the loss in head of draft and friction. Chimney will be 44 ft. in height above the ground and 2 ft. internal diameter.

14 cu.yds. of concrete required for foundation @ $8.00 per cu.yd. placed	$112.00
10,000 hard common brick at $7.00 per 1000 delivered on track at Mahomet	70.00
Labor for erection	50.00
Lightning protection	10.00
Total cost of stack	$242.00

Complete Set of Line Tools.

Two long handle shovels @ $1.50 each	$ 3.00
" " " spoons @ 1.50 "	3.00
" Short " shovels @ .90 "	1.80
" tamping bars. . . . . @ .25 "	.50
Cant hook	1.00
Carrying hooks	1.50
Two 14' pike poles . . @ $1.30 each	2.60
" 12' " " . . @ 1.05 "	2.10
Raising jenny	3.50

Come along, or wire clamps	$ 1.50
Blocks	1.50
200' of $\frac{1}{4}$" rope @ .09 per pound	.40
Brace and bits	1.80
Bolt cutters	4.00
Ax	1.25
Fraiming chisel	.40
Drawing knife	1.10
Saw	1.00
Connectors	1.60
Pliers	1.80
Belt	1.00
Safety belt	1.00
Climbers	2.50
Total cost	39.85

Summary of Costs.

Secondary distribution	$2080.80
Primary and incandescent circuits . . .	2301.05
Engine	1005.00
Boiler	798.00
Generator	861.00
Exciter	69.00
Boiler feed pump	59.00
Large pump	253.00
Heater	125.00
Injector	40.50
Separators Steam	47.00

Separators Oil	$ 51.00
Steam trap	15.50
Safety valve	12.50
Lubricators	14.00
Gage	5.40
Water Column	12.00
Damper	7.00
Foot valve	2.10
Float	7.00
Steel tank	18.50
Steel passage to stack	30.00
Piping complete	399.60
Belting	39.80
Lightning protection	100.85
Switch board	367.20
Building	2201.60
Switch	162.00
Trench for pipe line	64.00
Chimney	242.00
Complete set of line tools	39.85
Total cost of power station complete.	11421.25

Finances.

From load curves it is found that 45 K.W. Hr. are sold each night during the winter months; 21.6 K.W. Hr. are sold each night during the spring and fall months and 7.8 K.W. Hrs. are sold each night during the summer months. Total amount of power sold during the year is 7240 K.W. Hr. 7240 K.W. Hr. at 15¢ is $1086.00

Receipts for street lighting.

Forty-seven incandescent lamps at $1.25 per month and three arc lamps at $5.00 per month. Total receipts for street lighting for one year is $985.00

Receipts for pumping 15,000 gal. of water per day for 365 days in the year is $400.00.

Receipts.

For Commercial lighting -	$1086.00
" Street lighting . . .	985.00
" Pumping water	400.00
Total	$2471.00

Principles that govern rates of charges.

The power plant at Mahomet is an independent monopoly and has the power to fix the price of selling electricity. Prices charged will tend to be adjusted so as to yield the largest net income. In determining what prices will yield the highest net return the following principles are recognized; first, as the plant decreases the ——— — —— out put it increases its margin utility; second, certain expenses of generating power will increase or decrease nearly proportional, with each increase or decrease of power; third, other charges are nearly the same whether the out put is large or small. In determining the rates of charge for electricity in order to secure the maximum net revenue, the fixed expenses will be disregarded, and will consider first, the amount of electricity demanded at various prices, and second, the variable expense with increase of supply.

The rates will not be the highest prices that it could compel a consumer to pay; but will lower prices whenever the increase in demand will more than counter balance the reduction in charges and the increase of the variable expenses.
Taking these principles into consideration, it is found that the maximum income will be when electricity is sold at 15¢ per K.W. Hr. If 20¢ was charged per K.W. Hr. the power out put would be small, as less people would buy and the income will be less. If 10¢ is charged per K.W. Hr. on the other hand, there will not half as many more people take lights, than have lights already. So in both cases the receipts would be less than if 15¢ per K.W. Hr. was charged. For this reason that the maximum receipts are realized at 15¢ per K.W. Hr. this is the rate charged. The flat rate of $1.25 per month for series incandescents and $5.00 per month for arc also give the maximum net receipts.

The price charged for pumping water for the railroad company must be less than what they are now paying to get the pumping done, or they will not change from their present method of pumping. It is estimated that the present cost to pump 15,000 gallons of water 365 days a year is $450.00.
As no extra cost will be added to the operating expenses, and the only added expenses are, the coal consumption, depreciation taxes, interest and insurance it is found that the pumping could be done for $400.00 a year. This would be at the rate of $.00064 per cu.ft.

Coal Consumption.

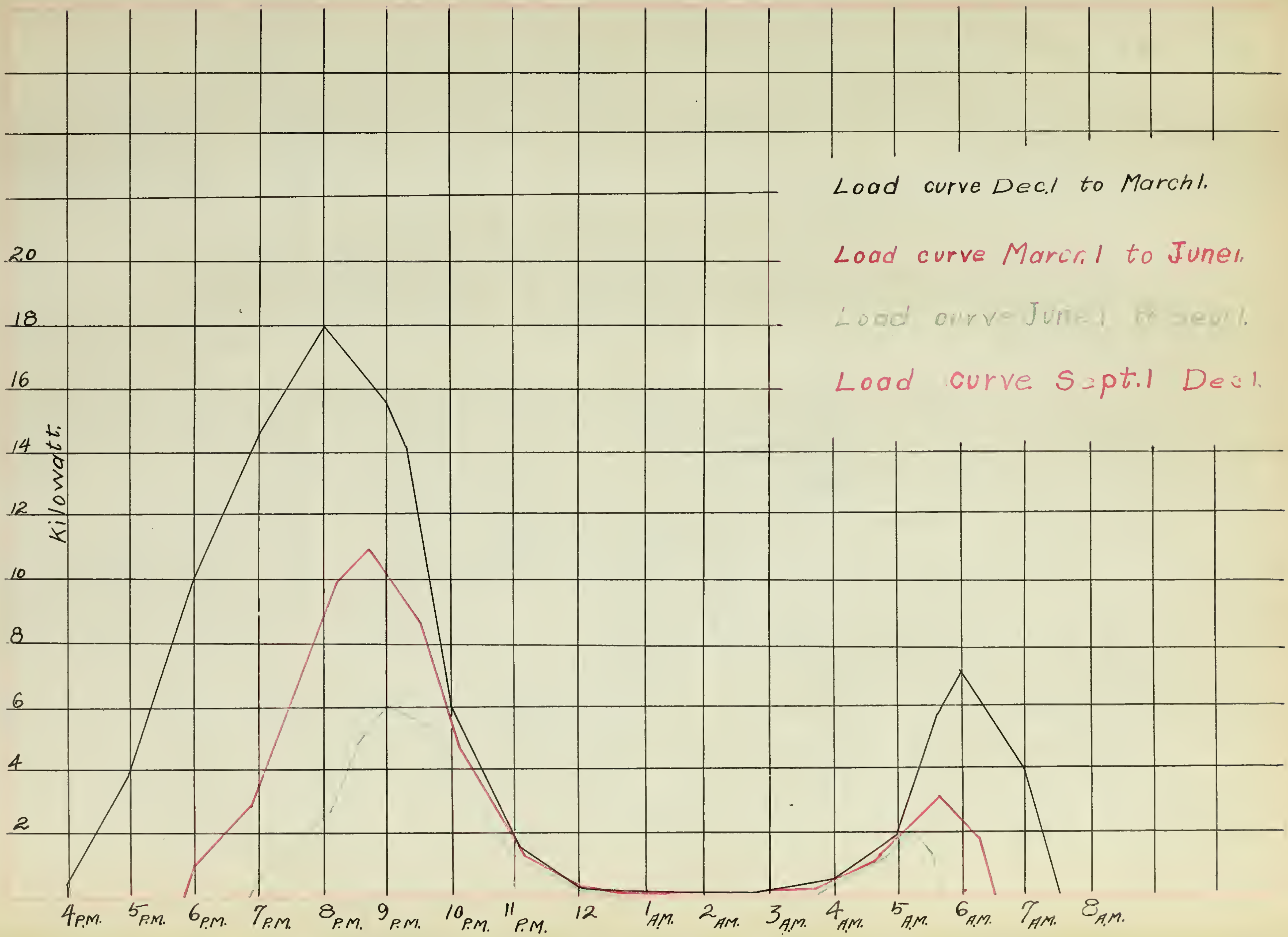
The coal consumption is calculated from the required number of pounds of steam need per year. It is found that 568,500 pounds of steam is necessary; but since the fire dies down each day, twenty-five per cent more of coal is consumed in starting the boiler. This gives 90 tons of coal, allowing one pound of coal to evaporate four pounds of water.

Expenditures.

Depreciation .04, repairs .02, insurance .01, and Taxes .01 @ .08 is	$913.70
Operator @ $50 per month	600.00
Lineman and Collector @ $35.00 per month	420.00
Oil and waste	25.00
Other petty expenses	60.00
Coal 90 tons @ $1.25 per ton	112.50
Total	$2131.20

This gives $339.80 as the interest, which is only three per cent on the investment. Money invested in such an undertaking as this usually requires a higher rate of interest, as there would be a risk to take. This shows that money invested in the above designed power plant would be unprofitable as only three per cent interest is received and no allowance has been made for the management of the plant.

It would be more profitable to loan the money at ~~one~~ six per cent interest and then there would be no risk. If the load factor could be increased to .15 instead of .10 the above plant as designed would prove a good investment.


Load curve Dec.1 to March1.
Load curve March1 to June1.
Load curve Sept.1 Dec.1
Kilowatt.
20
18
16
14
12
10
8
6
4
2
4 P.M.
5 P.M.
6 P.M.
7 P.M.
8 P.M.
9 P.M.
10 P.M.
11 P.M.
12
1 A.M.
2 A.M.
3 A.M.
4 A.M.
5 A.M.
6 A.M.
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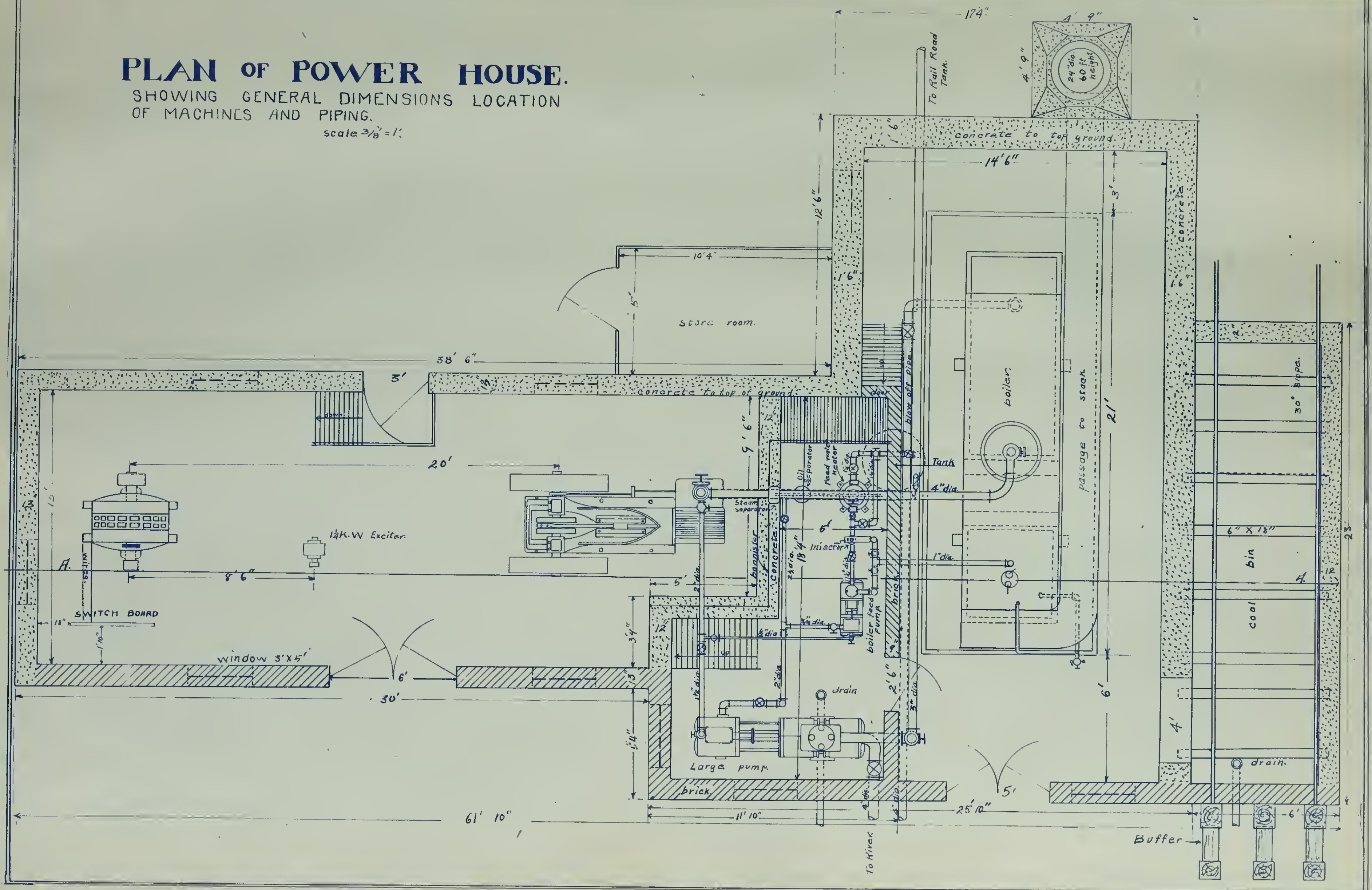
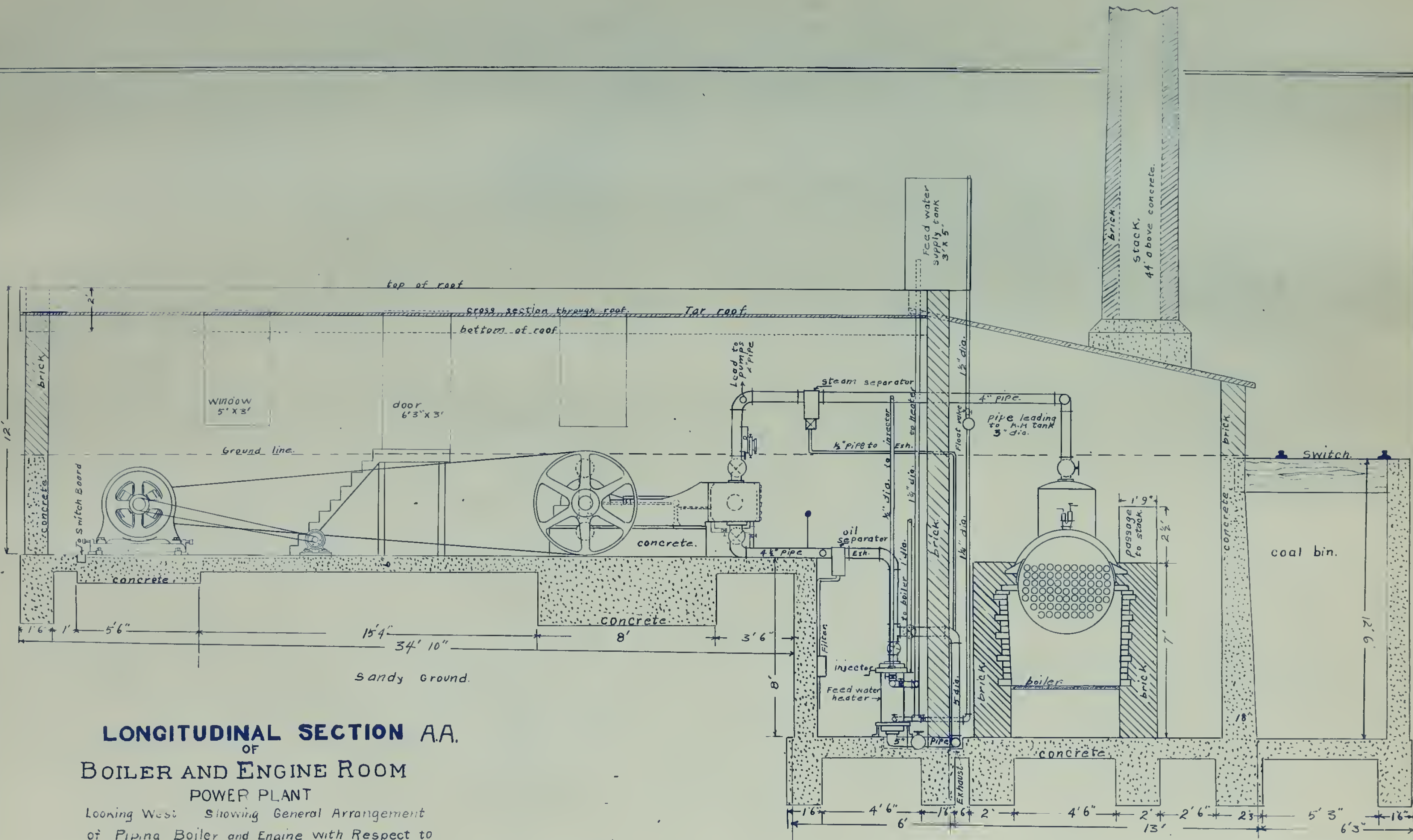
8 A.M.

PLAN OF POWER HOUSE.

SHOWING GENERAL DIMENSIONS LOCATION OF MACHINES AND PIPING.

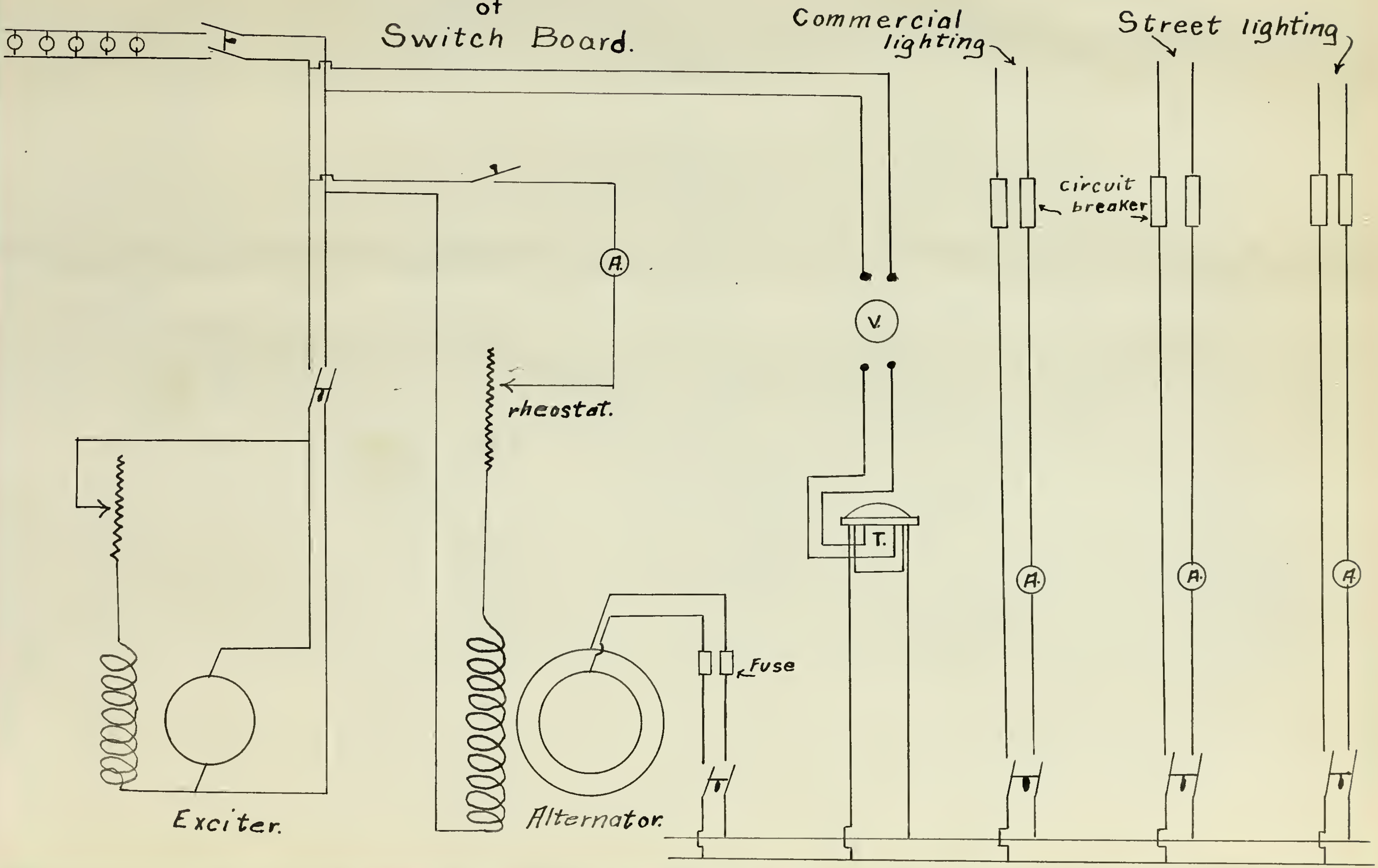
scale 3/8" = 1'.

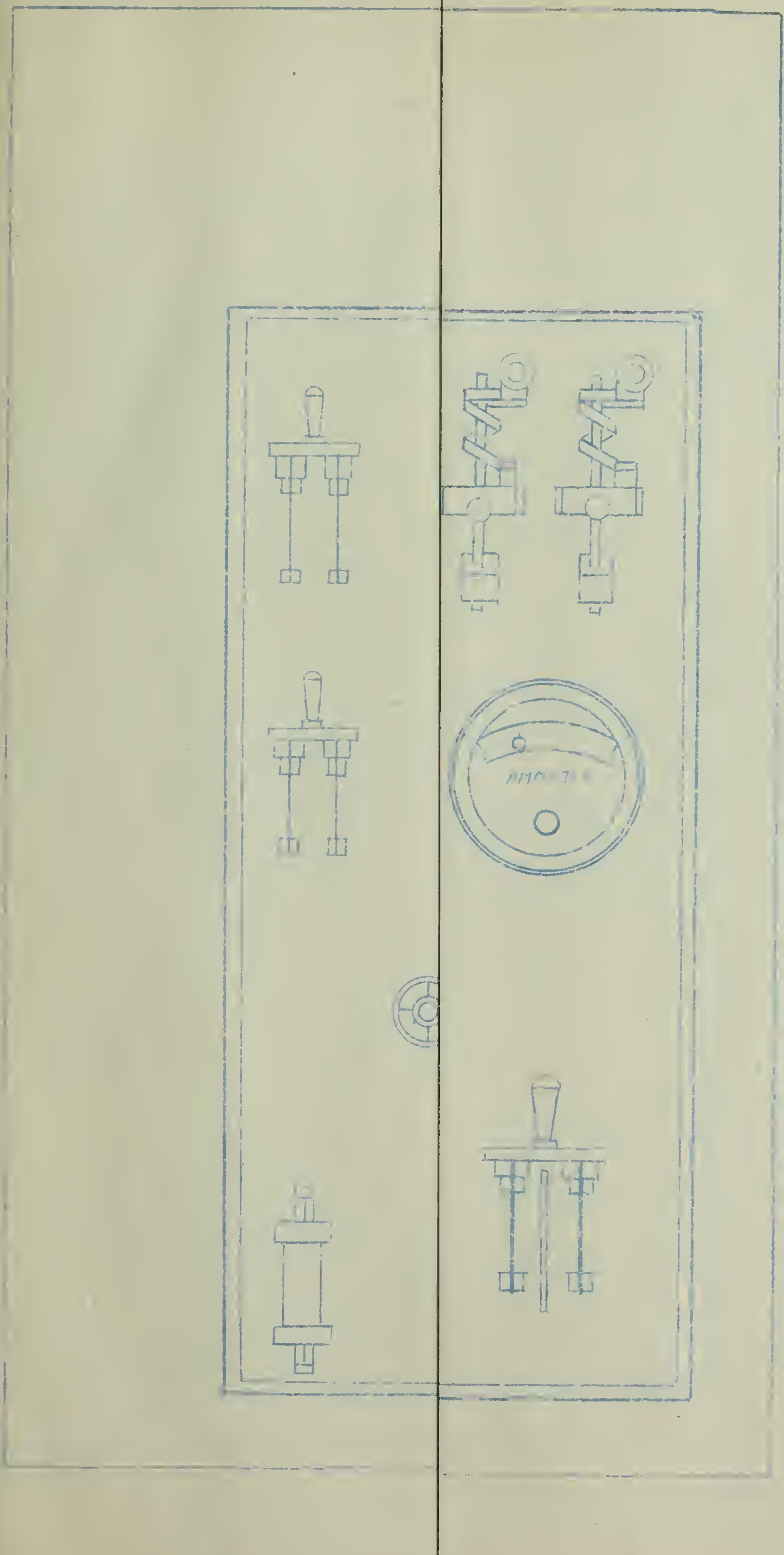




LONGITUDINAL SECTION A.A.
OF
BOILER AND ENGINE ROOM
POWER PLANT
Looking West Showing General Arrangement of Piping, Boiler and Engine with Respect to Alternator.
Scale $3/8" = 1'$

Wiring Diagram
of
Switch Board.

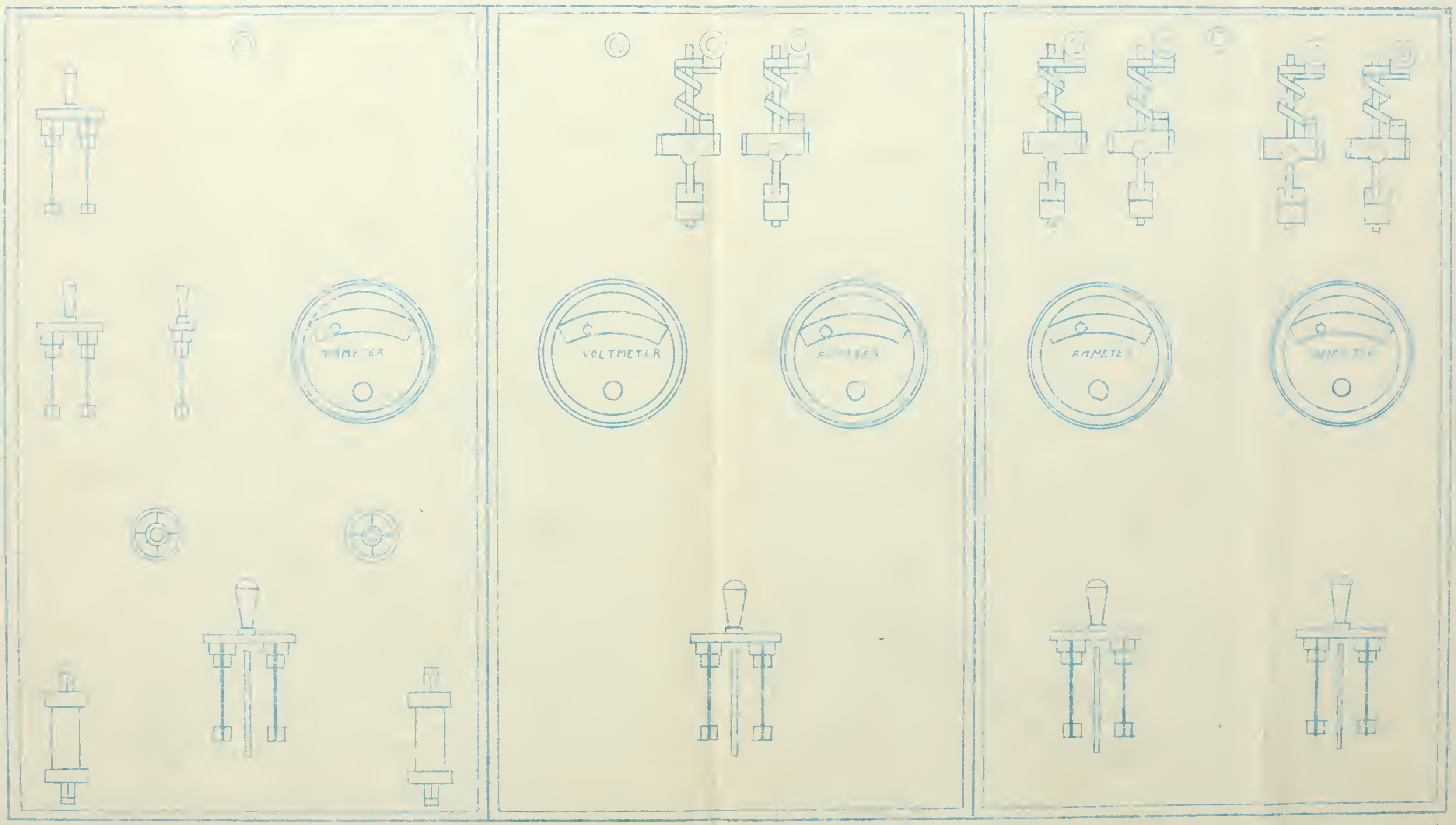


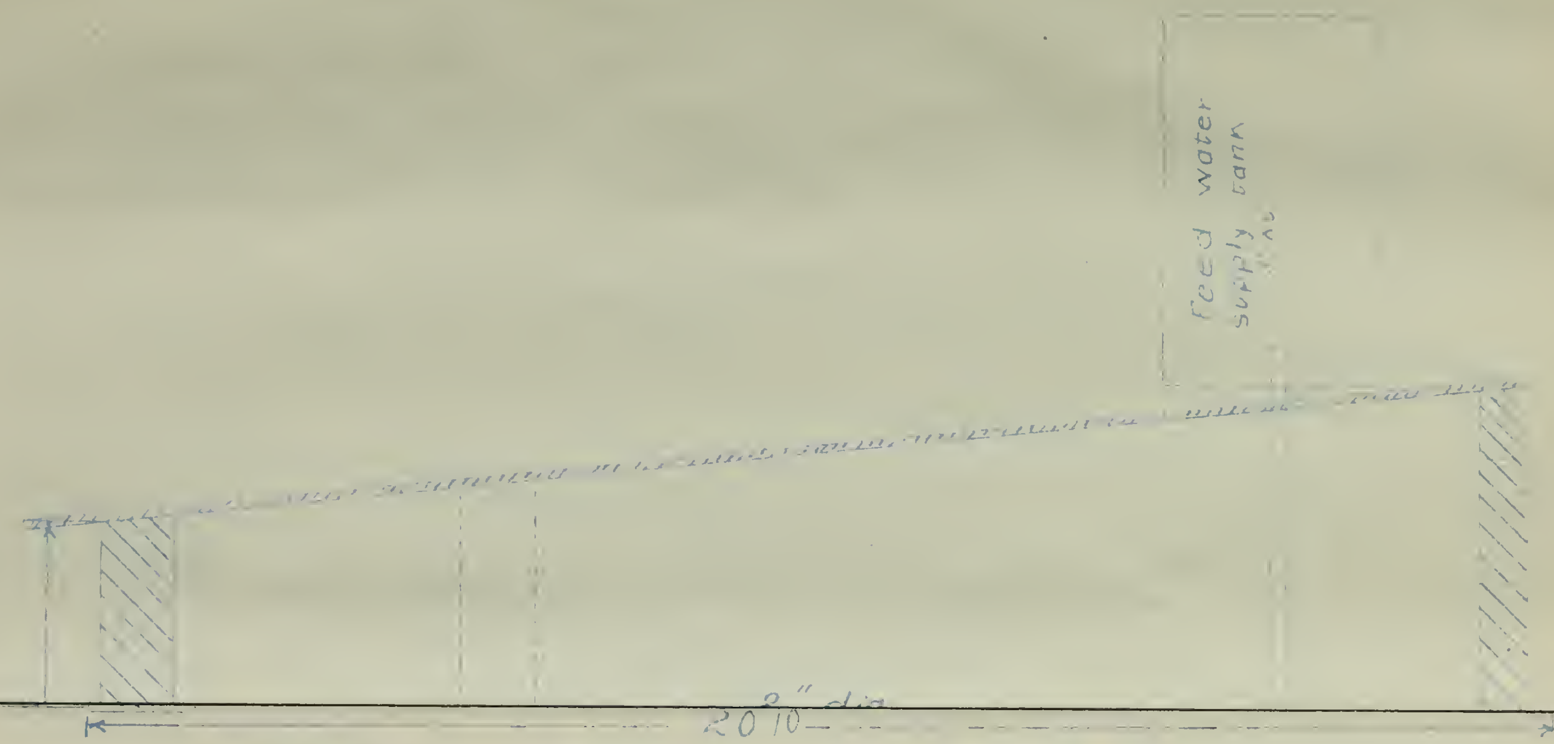


SWITCH BOARD

SHOWING LOCATION OF INSTRUMENTS

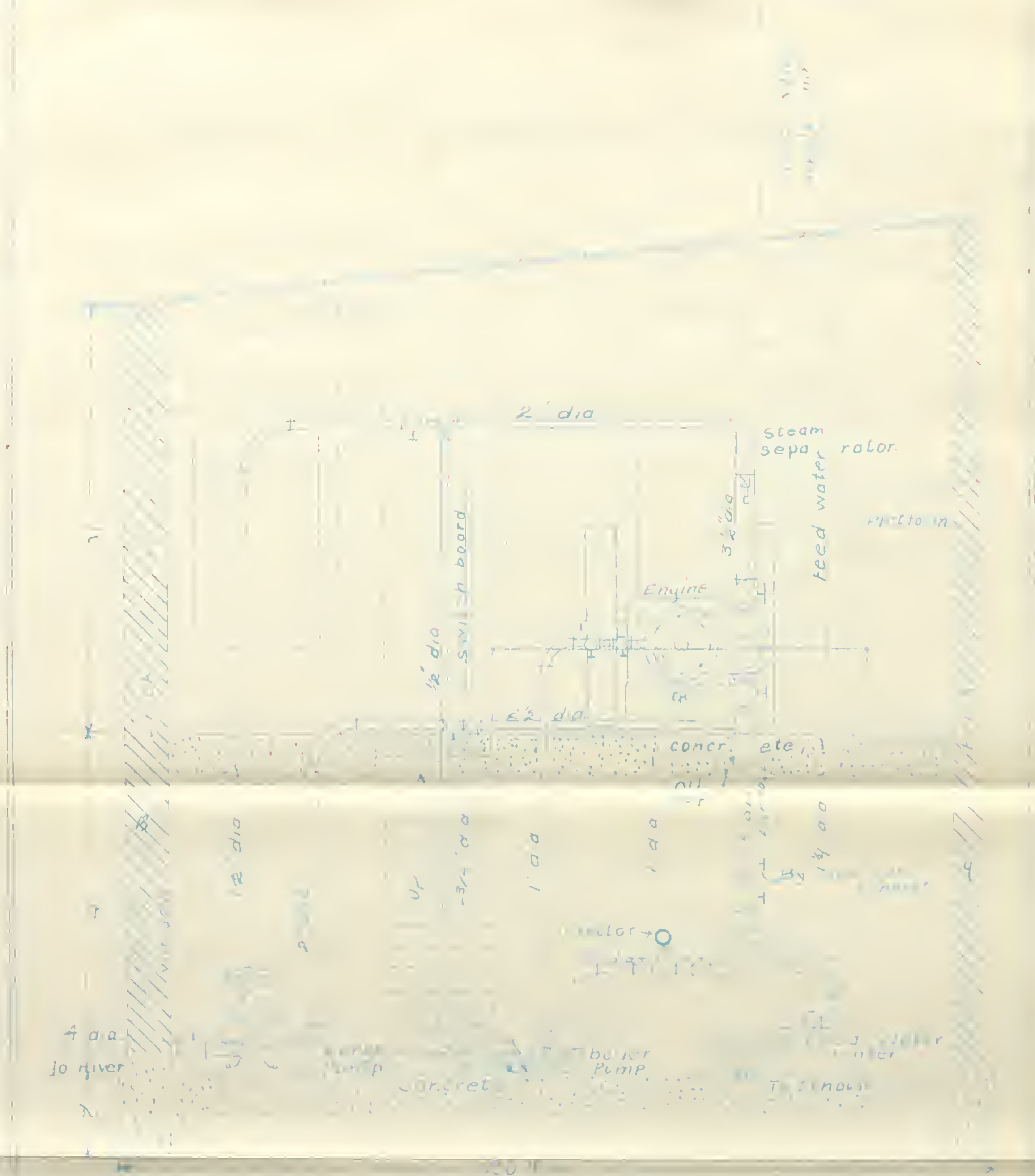
AND WIRING DIAGRAM





LONGITUDINAL SECTION
OF
PUMP ROOM.

section by partition wall looking south
scale 3/8" = 1'.



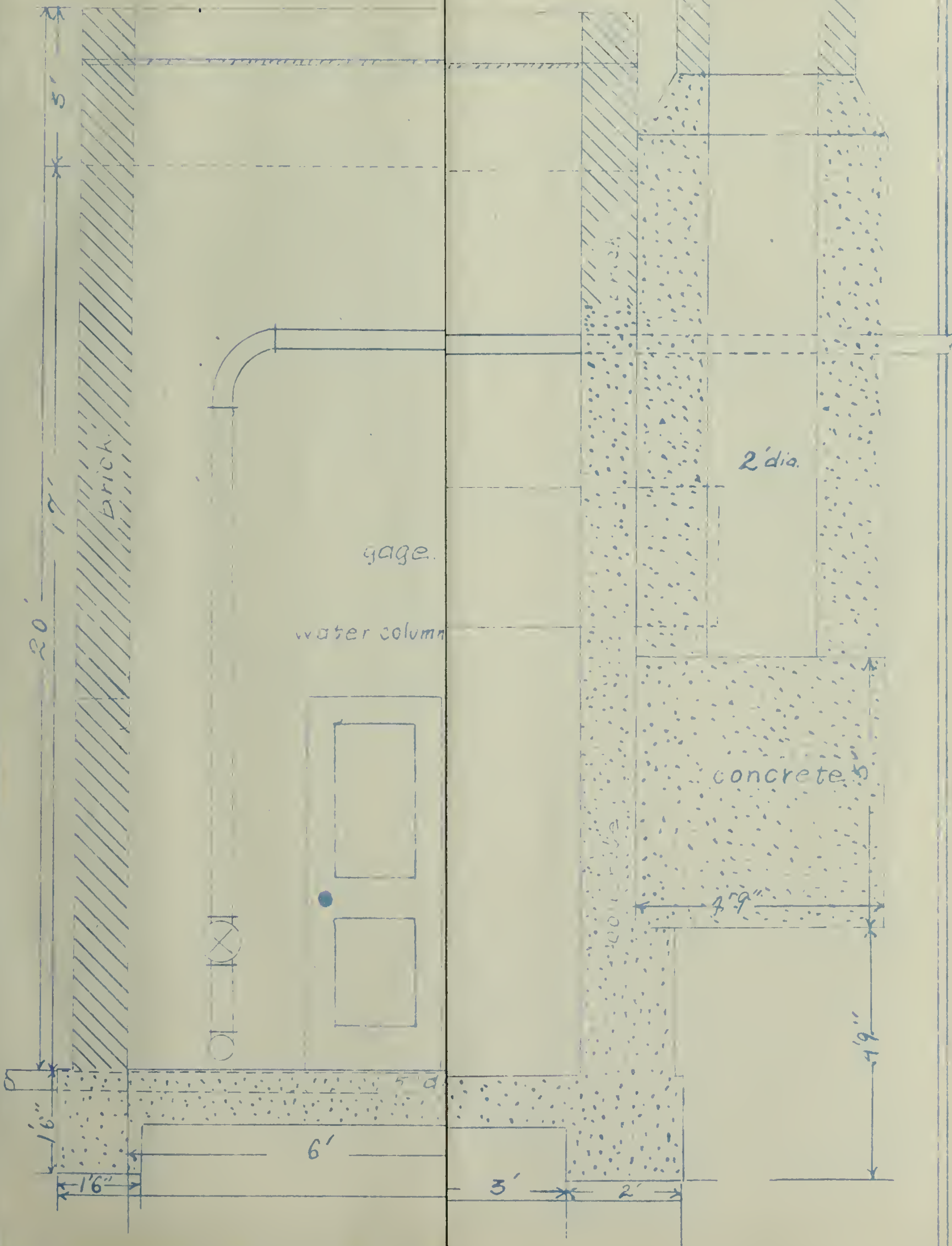
LONGITUDINAL SECTION

OF

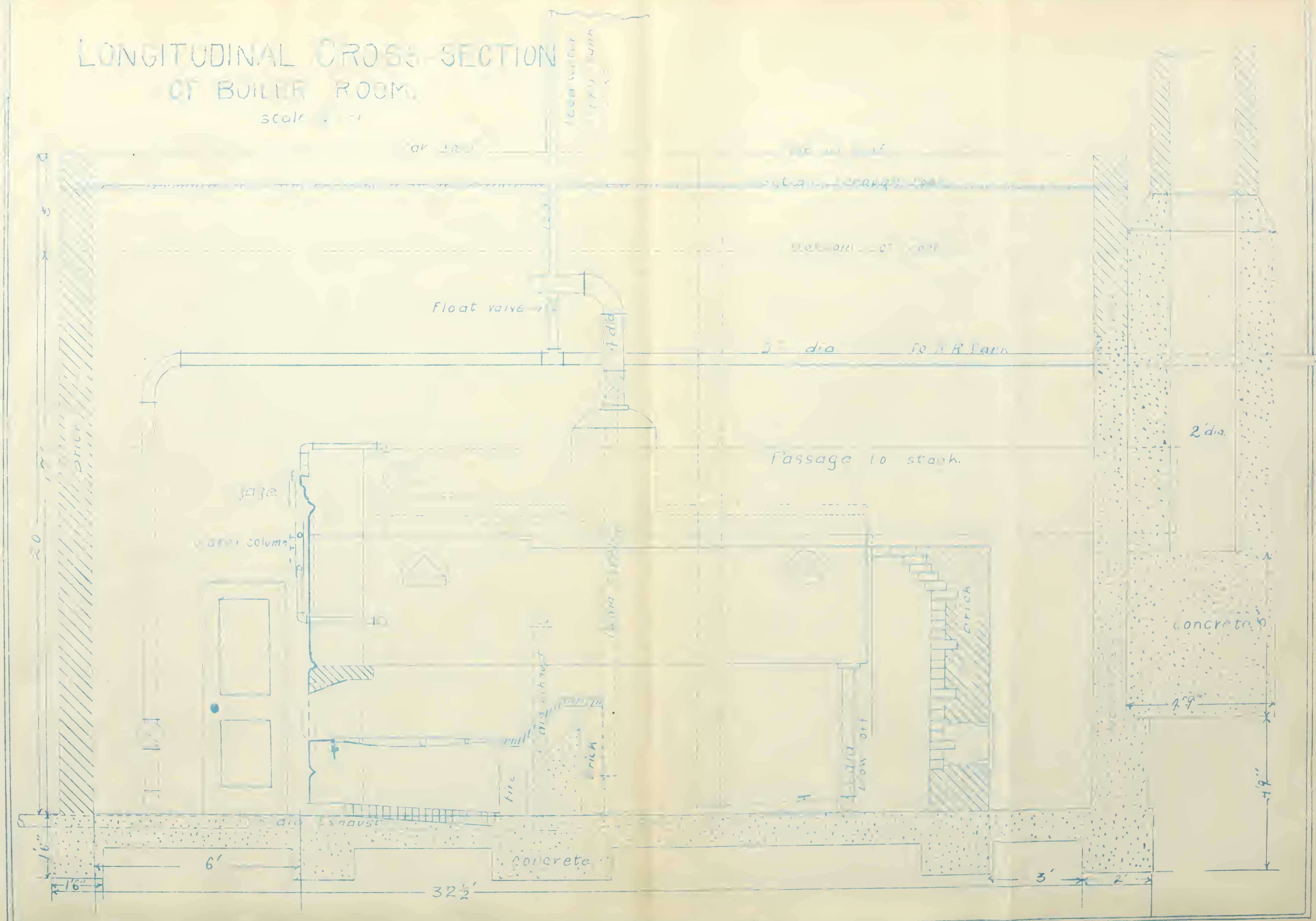
PUMP ROOM.

Scale 5/8"

LONGITUDINAL
OF BOIL
SC



LONGITUDINAL CROSS-SECTION OF BOILER ROOM.



MAHOMET.

Showing location of dwelling and business district
and the estimated number of lights per house
Also showing location of poles and power-house,
primaries and transformers.
scale 1" = 200


MAHOMET.
Showing location of dwelling and business district
and the estimated number of lights
Also showing location of poles and power-house,
series incandescent circuit and lamps.
scale 1 - 200
WEST
MAIN
ST
FRANKLIN
ST
DUNBAR
ST
UNION
ST
OAK
ST
FILMORE ST.
SANGAMON
ST
ADAMS ST
WASHINGTON
ST
JACKSON
ST
WALNUT
CENTER
VINE
ELM
DIVISION
MARKET
JEFFERSON
LOMBARD
CHURCH ST
LINCOLN
CEMETERY
SCHOOL
CHURCH
business district
CLEVELAND CINCINNATI CHICAGO AND
ELEVATOR
MILL
DEPOT
TILE YARD
LUMBER YARD
LUMBER CO
POWER HOUSE
SANGAMON RIVER
N.
S.
E.
W.